May 2014

WORKING PAPER SERIES

2014-EQM-04

A Directional Distance Function Approach to Identifying the Input/Output Status of Medical Residents

Gary D. Ferrier
University of Arkansas

Hervé Leleu
CNRS-LEM and IESEG School of Management

Vivian V. Valdmanis
University of the Sciences in Philadelphia

Michael Vardanyan
IESEG School of Management (LEM CNRS)

IESEG School of Management
Lille Catholic University
3, rue de la Digue
F-59000 Lille
www.ieseg.fr
Tel: 33(0)3 20 54 58 92
Fax: 33(0)3 20 57 48 55

A Directional Distance Function Approach to Identifying the Input/Output Status of Medical Residents

Gary D. Ferrier
Department of Economics
University of Arkansas
Business Building, Room 402
Fayetteville, AR 72701, USA
Email: gferrier@walton.uark.edu

Hervé Leleu
CNRS / LEM and
IÉSEG School of Management
3 Rue de la Digue
59000 Lille, France
Email: h.leleu@ieseg.fr

Vivian G. Valdmanis
Health Policy Program
University of the Sciences in Philadelphia
600 South 43rd Street
Philadelphia, PA 19104, USA
Email: v.valdma@usciences.edu
Affiliate Professor
IÉSEG School of Management
3 Rue de la Digue
59000 Lille, France

Michael Vardanyan
IÉSEG School of Management (CNRS LEM)
1, Parvis de la Défense
92044 Paris La Défense, France
Email: m.vardanyan@ieseg.fr

February 2014

The application of the human capital theory, the production theory, and the comparison of costs between teaching and non-teaching hospitals all point to the difficulties in identifying whether medical residents should be considered as inputs or outputs. We add to the debate by using a data-driven parametric approach based on the directional technology distance function to determine the status of medical residents. Using the American Hospital Association data from 1994 to 2010 we show that residents are inputs in all rural and in public non-teaching hospitals, but outputs in urban-area teaching not-for-profit hospitals. We also demonstrate that the status of residents is related to the case-mix index and that it can sometimes vary with hospital size.

Keywords: hospitals, directional distance functions

JEL Classification: C13, D24, I12

1. Introduction

A vexing question in health economics is the role of medical residents, i.e., physicians in training. The reason for this question to be raised is the attribution of higher costs to teaching hospitals and whether these additional costs are worth it in terms of the social and medical benefits. One the one hand, if these physicians in training are inputs then they need to be treated as such on the input side that explains the cost structure of teaching hospitals. On the other hand, if residents are outputs, they convey a future social benefit as members of a well trained medical resource. Using innovative econometric techniques, we aim to answer this question particularly as changes in the United States health care system take shape.

The Affordable Care Act (ACA) of 2010, the health care reform passed during the first Obama administration, has been a source of interest, particularly the portions of the law addressing the individual insurance mandate, the elimination of pre-existing conditions, the extension of coverage of dependents on their parents insurance until the age of 26, and the amount of revenue allocated to the expansion of health care insurance coverage or reduction in price by between 80 and 85%. One aspect of this law that has not received much attention in the literature is the change in Medicare/Medicaid financing of post graduate medical education, i.e., the training of medical residents in teaching hospitals. A possible reason for this omission in the literature is that there has been no consensus in the literature whether medical residents are inputs in the production of patient care or outputs as the recipients of medical education. One issue that was never resolved was whether medical residents could be inputs at one type of hospital and outputs at another type of hospital. In the US, the Council of Teaching Hospitals (COTH) hospitals provide the majority of medical residency training, whereas other hospitals, while not members of COTH have minor teaching programs permitting medical residents more hands on patient care. Given this system, in some cases medical residents are being taught and in other cases provide general medical/surgical care.

Given the system in the US, there are two types of funding from Medicare (the single largest provider of funding for medical education). The direct graduate medical education (DGME) grants hospitals payments for residents salaries – implying that medical residents are inputs and the DGME is the price of these inputs. The other form of payment from Medicare is the indirect medical education (IME) fund which compensates hospitals for treating patients with higher severity of illness as well as additional financing for sophisticated services such as level I trauma centers, burn units, and other services (AAMC, 2013). It appears logical that the education of medical residents comes from the IME since under this arrangement they do not contribute to the production of patient care, rather attending physicians (senior post-residency doctors) do most of the direct care (or oversight) of patient care. In the past, the IME was approximately 7.5% but reduced to 5.5%; changes in the ACA require that this percent would further cut the IME percent to 4.95%. (The Bowles-Simpson Panel advocated for a cut to 2.2 %.) The change given in the ACA would result in a 9 billion dollar cut over 10 years and this change was advocated so that the patient care coverage under Medicare would not be cut (Rye, 2012).

Continuing with this logic, the DGME would be the financing tool for residents as inputs. It appears that the DGME payment is for the direct hiring of residents, hence they are inputs. The IME is a payment for the teaching and resource costs for teaching, therefore, residents are outputs. The difference lies in how best to define medical residents and the policy implication is how best to pay them – directly or indirectly to the hospital or as the Congressional Budget Office (CBO) suggested a combined payment. We propose addressing the issue of residents in hospital productivity – answering the question are they inputs or outputs?

One reason that the federal government in the US should be interested in this issue is because according the standard welfare economics, it still has the responsibility to provide the social good of an ample supply of doctors for the future as well as the public good of a well trained medical doctors.

As stated above, there has been no consensus in the literature whether medical residents are inputs or an output which is crucial .in making policy suggestions. We add to the medical residents question by relying on the methodology outlined in Guarda et al. (2013), who demonstrate how directional distance functions can be used to assess the status of variables as inputs or as outputs.

2. Background

The literature has focused on three areas of medical residents. The first is the human capital theory, the second is their role in the production of hospital patient care, and finally the higher costs associated with teaching hospitals. We briefly review each of these strands of the literature below.

Human capital theory as described by Becker (1962) has been applied to the training of medical residents. Specifically, human capital theory stipulates that because medical residents receive general training from teaching hospitals they should bear the additional costs of this training (Newhouse and Wilensky, 2001; Nicholson and Song, 2001). This payment is embodied as accepting a wage rate that is lower than their marginal revenue product. The application of the human capital theory can divide the DGME into the reduced wage allocated to resident salaries with the difference between the marginal revenue product and the DGME payment as the investment in human capital since they can take the skills learned as a resident and apply them at any hospital/practice as a fully trained physician. In this case, the hospital can reap benefits from the residents adding to the output of patient care while being paid less than attending physicians. The DGME also provides hospitals with incentives to hire more residents since it reduces the cost of hiring a resident and this incentive would be accentuated particularly if the residents could be employed as substitutes to more expensive inputs. Therefore, the human capital theory along with the DGME suggests that residents are inputs.

Production studies have examined medical residents as inputs and outputs. Grosskopf, Margaritis, and Valdmanis (2001) examined whether medical residents congested the production of patient care. These authors reported that medical residents did congest the production of patient care and hospitals with the higher ratios of medical residents to beds, referred to as teaching intensity, was positively and significantly related to higher levels of congestion. Nicholson and Song (2001) contended that if the hospital production function was homothetic, that the reduced amount of patient care produced should lead to decreases in the proportional employment of inputs, therefore, if patient care production is compromised as described by Grosskopf et al., (2001) then following Nicholson and Song (2001), fewer residents would be hired when congestion arises. In both these approaches, medical residents were treated strictly as inputs.

The third focus in the literature is on the difference between teaching and non-teaching hospital costs. Sloan et al., (1983), Lee and Hadley (1985) and Cameron (1985) all argued that for hospital cost differentials to be meaningful both the direct and indirect costs of teaching had to be examined. In all these studies, authors reported that higher costs in teaching hospitals were attributed to medical residents using more ancillary services, ordering more tests, and therefore, extending length of stays for patients, all factors leading to higher costs (i.e., congestion). In several other studies including those by Feinglass, et al., (1991), Simmer et al, (1991), Lehrer and Burgess (1995) and Campbell et al., (1991) concluded that hospitals relying more on staff physicians rather than more on residents had lower costs than the case wherein residents were afforded more autonomy. The consistency of these findings demonstrated that even though residents may be lowered priced inputs vis-à-vis attending physicians the indirect costs of teaching hospitals dictated the higher costs results.

In most of these studies medical residents were considered as inputs in the production of patient care. Custer and Wilke (1991) estimated the hospital costs using the joint production of outputs which included inpatient care and medical residents. Wilensky and Newhouse (2001) found that the higher costs associated with teaching per se was not the cost driver, but rather the degree of specialization as well as the combination of a differentiated patient care product, subtle case mix differences and the costs of medical/clinical research. Since medical residents are not directly treating these medically compromised patients using the specialized services or leading research, but learning, the IME that has historically paid for this portion of teaching hospital costs, is consistent with medical residents are outputs.

In addition to the theoretical issues presented above, there are other practical issues that have arisen regarding teaching, hospital ownership form, and rural/urban distinctions. Public hospitals (state and locally owned) are traditional safety net hospitals regarded as the provider of last resort especially for the poor and uninsured (Norton and Staiger, 1994). As a trade off in providing this “free” i.e., no out of pocket payment care is to receive treatment from medical residents (Dower, 2012). This trade off is a benefit for the public hospitals since as stated above, medical residents are less expensive providers of medical care than experienced attending physicians. Given this community-hospital relationship, we would assume that medical residents are inputs in the public sector hospitals.

COTH hospitals are typically located in urban areas and as such, most of the DGME payments go to these hospitals. The problem here is that rural populations have insufficient access to medical specialists because of insufficient demand to justify the presence of medical sophistication (Dower, 2012). In the case of public hospitals, rural hospitals appear to be primed to provide good training grounds for medical residents to hone their treatment and diagnosis skills, given there are no attending physician alternatives.

Human capital theory, production theory, and the findings of hospital costs all point to the difficulties in identifying whether residents should be considered as inputs or outputs or to what degree they are both, the debate over funding and funding amounts and who bears the costs and benefits still needs to be resolved. Interestingly, the issue of medical residents has not been dominant in the literature since the 1990's. Therefore, we have two purposes for our study. First, it is our intent that by utilizing more sophisticated econometric modeling, we can ascertain the shadow prices of residents as inputs and outputs, and as such provide payers more information regarding DGME and IME financing. Second, we use more recent data to study the effects of medical residents during the 2000's. In the next section, we outline the theoretical background, estimation methods, and the dataset. We describe the results in section 4 and conclude the paper in section 5 with a discussion and policy implications.

3. Estimation Methods and Data

Following a standard practice, we assume that an N-dimensional vector of inputs, denoted by x, is used to produce an M-dimensional vector of socially desirable outputs, or y.

Residents are not designated a particular notation, since their status depends on the type of hospital technology and is unknown a priori. The underlying production technology can be described as $T = \{(x, y) \in \Re^{N+M} : x \text{ can produce } y\}$. Alternatively, it can be modeled via the output sets $P(x) = \{y \in \Re^{M} : (x, y) \in T\}$, which are given for a fixed input vector and the input sets $L(y) = \{x \in \Re^{N} : (x, y) \in T\}$, which rely on a fixed output vector. We assume further that the technology satisfies the standard axioms of production (Färe and Primont 1995).

One of the measures that can be used to approximate such a technology is the directional technology distance function (Chambers et al. 1996), which is closely related to more widely used Shephard (1953, 1970) input and output distance functions. The directional technology distance function approximates the distance from a particular observation to the frontier of the set *T*, and is defined with respect to a mapping vector, which specifies the direction in which this frontier is approached as the inputs are contracted and the outputs are expanded. It can be written as

(1) $$\vec{D}_T(x, y; g_x, g_y) = \sup\{\psi : (x - \psi g_x, y + \psi g_y) \in T\},$$

where $g_x \in \Re_{+}^{N}$ and $g_y \in \Re_{+}^{M}$ are the components of this mapping vector. Two special cases can be derived from the directional technology distance function by imposing restrictions on this vector. Assuming $g_y = 0$ yields the directional input distance function $\vec{D}_I(x, y; g_x, 0^M) = \sup\{\psi : (x - \psi g_x) \in L(y)\}$, which is dual to the cost function. Similarly, setting $g_x = 0$ produces $\vec{D}_O(x, y; 0^N, g_y) = \sup\{\psi : (y + \psi g_y) \in P(x)\}$, known as the directional output distance function, which is dual to the revenue function.[1] Besides approximating production technologies, directional distance functions can also be used to measure production inefficiency.

In our empirical illustration we will rely on the methodology outlined in Guarda et al. (2013), who demonstrate how directional distance functions can be used to assess the status of variables as inputs or as outputs. This approach, whose concise version is given below to make our presentation self-contained, allows us to avoid imposing assumptions regarding the status of medical residents that may be inconsistent with the data, such as treating residents as congesting inputs when they should instead be assumed to be outputs.. By designing the mapping vectors so that each has only a single nonzero component, we can obtain multiple econometric specifications that can be estimated using the stochastic frontier methods of Aigner et al. (1977). Each of them corresponds to a separate assumption regarding the input/output status of a single variable only, which appears as the model regressand. Conditional on this assumption, we can test the status of all other variables. For example, by designating the first component of the output vector the role of an output and specifying the mapping vector appropriately yields a composite error directional *output* distance function model with this particular output as its regressand, i.e.[2]

$$y_1 = \vec{D}_O\left(x, 0, y_2, ..., y_M\right) + \varepsilon - u, \tag{2}$$

[1] See Färe and Grosskopf (2004) for a more in-depth description of modeling production technologies using directional distance functions and duality.

[2] The mapping vector's only nonzero component must correspond to the model regressand, i.e. $g_y = \left(1, 0^{M-1}\right)$. See Guarda et al. (2013) for details.

where ε is a standard *iid* error term and u is a non-negative error component, which measures inefficiency. Parameter estimates corresponding to this specification can then be used to recover the estimated coefficients of the underlying output distance function, or $\vec{D}_O\left(x, y; 0^N, 1, 0^{M-1}\right) \equiv u$, which assumes that only y_1 is allowed to expand as we approach the output set frontier.[3] Note that no ex ante assumptions regarding the status of any of the regressors in equation (2) need to be imposed, even though some of them are expected to appear as outputs and others as inputs. This useful feature will allow us to treat all of our variables as netputs and to rely on the data in order to identify the status of medical residents instead of imposing it on a priori grounds.

Any of the remaining $M-1$ outputs can also be used as regressands in order to define additional econometric specifications. Alternatively, we can assume that x_n is an input and instead estimate *N* directional *input* distance functions:

$$-x_n = \vec{D}_I\left(x_1, ..., x_{n-1}, 0, x_{n+1}, ..., x_N, y\right) + \varepsilon - u. \quad (3)$$

Consistent with many existing studies that have estimated parametric directional distance functions, we choose the quadratic functional form, or a second-order Taylor series approximation, in order to assign a parametric structure to functions appearing on the right-hand side of specifications (2) and (3). The quadratic function represents a suitable choice not only

[3] A directional distance function always takes values from zero to positive infinity and is unobservable, meaning that it can be set equal to a random variable with appropriate support, i.e. a random variable like *u*. Studies have traditionally assumed a half-normal distribution for this purpose.

because it has very good approximation properties (Färe et al. 2010, Chambers et al. 2013), but also because each econometric specification that is obtained by assuming orthogonal mapping vectors contains a vector of zeros as one of its arguments—a feature that cannot be accommodated by some other flexible functional forms, such as the translog function. Hence, taking the case of the output distance function given in (2) and denoting its corresponding netputs by z yields the following result:

$$Y_1 = \alpha_0 + \sum_{n=1}^{N} \alpha_n z_n + \sum_{n=N+2}^{N+M} \alpha_n z_n + (1/2)\sum_{n=1}^{N}\sum_{n'=1}^{N} \alpha_{nn'} z_n z_{n'} + (1/2)\sum_{n=N+2}^{N+M}\sum_{n'=N+2}^{N+M} \alpha_{nn'} z_n z_{n'} + \sum_{n=1}^{N}\sum_{n'=N+2}^{N+M} \alpha_{nn'} z_n z_{n'} + \varepsilon - u. \tag{4}$$

In order to determine each netput's role in the hospitals' production process we need to assess the monotonicity property of the estimated distance function u. This property required a directional distance function to be nonincreasing in outputs and nondecreasing in inputs, so we can study the sign and statistical significance of its partial derivative with respect to corresponding netputs to shed light on hospital technology. In the case of variables whose status is unknown these results can be used in order to draw ex post conclusions about their status. On the other hand, we can use partial derivatives with respect to variables whose input or output status is subject to relatively little debate in order to assess how well any particular econometric specification fits the data. In other words, the average fraction of monotonicity violations with respect to these variables can be used as a criterion for choosing the 'best' model among all specifications that can be defined using orthogonal directional vectors.

In our empirical illustration we rely on the American Hospital Association's data covering a period from 1994 to 2010. We choose variables that are commonly used to approximate hospital technology, such as the number of staffed and licensed beds (X_1), the number of full-time equivalent registered nurses (X_2), the sum of full-time equivalent licensed practical nurses and other personnel (X_3), the number of medical residents (R), as well as two variables, denoted by Y_1 and Y_2, which we constructed as indices in order to approximate hospitals' inpatient and outpatient activity. We define the inpatient care index as the sum of the number of admissions (A) and inpatient surgeries (IS), adjusted using the share of inpatient surgeries in this sum and multiplied by the hospital-specific case-mix index (CMI), i.e.

$$Y_1 = (A + IS)\left(1 + \frac{IS}{A + IS}\right)CMI\ . \tag{5}$$

Since treating an admitted patient and performing a surgery are activities that are expected to differ in terms of their corresponding resource intensity, multiplying their sum by the share of the more input-demanding output makes our approximation more sensible. Also, by adjusting this proxy with the associated case-mix index allows us to distinguish among hospitals that specialize in treating illnesses of various degree of difficulty. The second output index approximates the outpatient activity of a hospital. It is specified as the sum of the number of scheduled outpatient visits (O), emergency room visits (E), and outpatient surgeries (OS), adjusted using the share of emergency room visits and outpatient surgeries in this sum:

$$Y_2 = (O + E + OS)\left(1 + \frac{E + OS}{O + E + OS}\right). \tag{6}$$

Such aggregation allows us to avoid imposing relatively unrealistic assumptions regarding a trade-off between different outputs appearing as components of (5) and (6), which would be necessary if we treated them as separate outputs.[4]

Hence, we can define five econometric models, each corresponding to a single restriction placed on either one of the two variables we expect to be outputs or one of the three other variables we anticipate to have the status of inputs. The only variable that we did not restrict in any of the models is the number of medical residents, reflecting our lack of information regarding their role in the production process. Partial derivatives with respect to netputs entering each econometric specification can be used to (1) assess how well any individual specification fits the data, (2) determine the status of residents, and (3) examine whether our results are consistent across various specifications that can be defined.

Our pooled sample contains 53,590 observations corresponding to 4,025 individual hospitals that were active during at least six out of seventeen years we consider.[5] This total varies from the lowest of 2,345 individual hospitals in 2010 to the highest of 3,638 in 1999.

---

[4] During the initial stage of our analysis we used five disaggregated outputs, but the estimation results based on such a disaggregated output vector proved to be inconsistent with the theory. For example, when we defined an econometric specification similar to result (2) by assuming that admissions are outputs the corresponding output distance function's derivative with respect to inpatient surgeries and emergency room visits had a counterintuitive sign, suggesting that these variables are inputs.

[5] We have 1,196 hospitals that cover the entire 17-year period, representing 20,322 observations or approximately 38% of the sample.

Table 1 contains the means and the standard deviations (in parentheses) of variables used in estimation.

4. Results

We augment each econometric specification by including several sets of intercept and interaction dummy variables in order to discern different objective functions of hospitals and allow residents' status to vary accordingly. In particular, we distinguish between public, private not-for-profit (NFP), and private for-profit hospitals, between urban and rural area hospitals, as well as between teaching and non-teaching hospitals based on their affiliation with the Council of Teaching Hospitals (COTH). In order to allow these technologies to change with time we also include an intercept dummy for each year and a corresponding set of slope dummies. Since the technological progress among hospitals is likely to occur relatively slowly, only the dummies appearing on terms involving residents were included.

We first used the stochastic frontier approach popularized by Aigner et al (1977) to estimate a specification similar to result (4), in which the inpatient care index, or Y_1, was designated the status of an output. Estimation results revealed no evidence of inefficiency, suggesting that the same specification can instead be estimated using pooled OLS. Next, in order to assess how well this model fits the data, we used the OLS parameter estimates to obtain the average fraction of statistically significant monotonicity violations with respect to all of its unrestricted regressors except residents, as well as the average fraction of cases where monotonicity was statistically significant.[6] The overview of estimation quality based on this

[6] We calculated monotonicity at each data point and assessed its statistical significance at the 5% level with a one-sided t-test.

criterion is presented in Table 2 for each group of hospitals along with the size of each group.[7] Results suggest that this model is appropriate especially for the public and NFP hospitals, which together account for about 88% of the sample. For instance, the average fraction of statistically significant violations corresponding to the NFP urban non-COTH and rural non-COTH hospitals—our two largest categories that account for nearly 60% of the sample—equals just 0.2% and 0.3%, respectively. However, the results are less convincing for the for-profit hospitals.

We then proceeded to estimate the same specification using the random effects approach, but the approximation quality proved disappointing. For example, the distance function's partial derivative with respect to the outpatient care index (Y_2) had a counterintuitive sign for nearly all observations, implying no evidence of a tradeoff between the inpatient and outpatient activity and contradicting our corresponding OLS results. Similar conclusion was obtained when we used the remaining variables whose input or output status is generally known, or Y_2, X_1, X_2, and X_3, in order to define four additional econometric specifications. Regardless of the estimation approach, the approximation quality was always very poor compared to the results we obtained when we used OLS to estimate the model with the inpatient care index as its

[7] Besides urban non-COTH, rural non-COTH, and urban COTH-member hospitals, our sample also contains 33 rural COTH-member hospitals. Even though they were included in the sample during estimation, the results corresponding to this group are not reported due to its relatively small size.

regressand.[8] Since this specification does the best job of fitting the data, we will focus on its corresponding results for further analysis.

In Table 3 we present the findings regarding public hospitals. To review, only inpatient care is restricted to be an output, whereas the number of beds, registered nurses (RNs), other staff and outpatient care are not restricted along with residents. Recall, a negative sign indicates that a variable is an output; a positive sign designates an input. The findings in Table 3 indicate that beds, RNs, and other staff are inputs whereas outpatient care is an output indicating that inpatient and outpatient care may be substitutes. In public non-COTH urban and rural hospitals, medical residents are inputs which is consistent with the literature suggesting that medical residents are used as relatively less expensive medical staff inputs. Conversely, in public urban COTH hospitals there is no clear indication that residents are inputs or outputs, but interestingly, other staff appear as outputs, which may be attributed to the social mission of these hospitals for providing employment opportunities to the local population.

We report the NFP findings in Table 4. This type of hospital is by far the largest but the results are not as consistent in terms of outpatient care wherein the NFP sector, there is no statistical significance. Consistent with the public hospitals, medical residents are considered as inputs. Interestingly, in the Urban COTH hospitals, medical residents are considered as outputs.

[8] For example, the input distance function-based specification that designates the number of beds the status of an input consistently violates monotonicity with respect to the number of nurses and the sum of licensed practical nurses and other personnel, whereas the specification that assumes that the outpatient care index is an output often violates monotonicity with respect to the number of beds and the inpatient care index.

In the for-profit hospital sector (Table 5) the approximation quality is not as good as in the case for either the public or NFP hospital sectors. The only interesting finding is that in for-profit hospitals, outpatient care is deemed as an input, suggesting that outpatient and inpatient care are complements. There is no interesting findings regarding medical residents but this may be due to the small number of these hospitals in the COTH sub-sample.

One reason why medical residents may be inputs or outputs is the case mix index of the patients treated by the hospital. We hypothesize that hospitals with less serious patients may be directly treated by the medical residents, whereas more seriously ill patients require the attending medical staff's attention, and as such as used as teaching cases for the medical residents' education. In Table 6, the findings relating case mix and medical residents' status is quite convincing. With hospitals with lower case mix indices, such as the public and NFP non-COTH hospitals, medical residents are inputs – in urban COTH hospitals, medical residents are considered as outputs (in 77% of the cases) which coincides with the very high overall case mix index of 1.71 (as compared to a mean for all hospitals in our sample of 1.30). In the for-profit sector, 96% of medical residents are considered as outputs in non-COTH hospitals with a case mix index of 1.38. However, there were few findings that were statistically significant in this sub sample.

As we noted above, the NFP sector is by far the largest sub sample of our overall sample, there was no systematic evidence how this large proportion can be summarized. One way, however, is to discern any differences by the size of the hospital. We divide the NFP sub sample defining small hospitals as those having the 25 percentile of beds and large hospitals as being at the 75 percentile of beds and summarize the results in Table 7. We found that in the large NFP urban hospitals, medical residents are outputs corresponding with a mean case mix index of 1.54. Conversely, in small NFP hospitals, 82% of medical residents are inputs corresponding with a lower mean case mix index of 1.13. In the medium sized hospitals, the findings are mixed so we surmise that we can make real statements of medical residents' status at the extremes.

5. Discussion

We applied a data driven parametric approach based on the directional technology distance function in order to determine the status of medical residents. Specifically, we are interested in determining whether they are inputs in the production of hospital care for patients or whether they are outputs as part of the function of teaching hospitals. Using a panel data set spanning sixteen years (1994-2010) we divided the total sample of hospitals by ownership form and rural/urban distinctions to better assess if medical residents are treated differently systematically by a hospital type.

In public non-COTH urban and rural hospitals residents are determined, using our approach, to be inputs as well as in not-for-profit hospitals, generally. Tying these findings to policy, it appears that the DGME should be directed to these hospitals representing payment for inputs consistent with human capital theory.

Conversely, urban COTH hospitals, especially those with patients presenting with higher case mix indices (more seriously ill) medical residents are outputs. Since teaching and higher case mix patients' treatments appear to be jointly produced in these hospital settings, greater attention to IME financing should be placed here.

We suggest that from our findings, better allocation of teaching monies could be applied by hospital type and medical residents' status rather than on averages and accounting methodologies. Focusing on ownership forma and the rural/urban distinctions, better finessed payment schemes could be developed enhancing the production of social goods while maintaining access to patients requiring safety net hospitals for treatment by the medical resident inputs.

References

Becker, G. (1962) “Investment in Human Capital: A Theoretical Analysis” Journal of Political Economy 70(5): 9-49

Newhouse, J., and G. Wilensky (2001) “Paying for Graduate Medical Education: The Debate Goes On” Health Affairs 20(2): 136-147

Custer, W. and R. Willke, (1991) “Teaching Hospital Costs: The Effects of Medical Staff Characteristics” Health Services Research 25(6): 831-857

Nicholson, S. and D. Song (2001) “The Incentive Effects of the Medicare Indirect Medical Education Policy” Journal of Health Economics 20:909-930

Grosskopf, S., D. Margaritis, and V. Valdmanis (2004) “Competitive Effects on Teaching Hospitals” European Journal of Operational Research 154: 515-525

Sloan, F., and R Feldman, and B. Steinwald (1983) “Effects of Teaching on Hospital Costs” Journal of Health Economics 2:1-28

Lee, R, and J. Hadley (1985) “The Demand for Residents” Journal of Health Economics 4: 357-371

Cameron, J (1985) “The Indirect Costs of Graduate Medical Education” New England Journal of Medicine 312(19): 1233-1238

Rich, E., G. Gifford, M. Luxemberg, and B. Dowd (1990) “The Relationship of House Staff Experience to the Cost and Quality of Inpatient Care” Journal of the American medical Association 263 (7): 153-171

Simmer, T., D. Nerenz, W. Rutt, C, Newcomb, D. Benfer (1991) “A Randomized Controlled Trial of an Attending Staff Service in General Internal Medicine” Medical Care 29(7): JS31-40

Lehrer, L. and J. Burgess (1995) “Teaching and Hospital Cost Production: The Use of Regression Estimates: Health Economics 4:113-125

Campbell, C. K. Gillespie, and J. Romeis (1991) “The Effects of Residency Training Programs on the Financial Performance of Veterans Affairs Medical Centers” Inquiry 28(3): 288-299

Grosskopf, S., D. Margaritis, and V. Valdmanis (2001) “The Effects of Teaching on Hospital Productivity” Socio-Economic Planning Sciences 35: 189-204

Rye, B. (2012) “Assessing the Impact of Potentical Cuts in Medicare Doctor-Training Subsidies” Rye Government Study

Aigner D, Lovell CAK, Schmidt P (1977) Formulation and estimation of stochastic frontier production function models. J Econom 6:21-37

Chambers RG, Chung Y, Färe R (1996) Benefit and distance functions. J of Econ Theory 70:407-419

Chambers RG, Färe R, Grosskopf S, Vardanyan M (2013) Generalized quadratic revenue functions. J Econom 173:11-21

Färe R, Primont D (1995) Multi-output production and duality: theory and applications. Kluwer Academic Publishers, Boston

Färe R, Grosskopf S (2004) New directions: efficiency and productivity. Kluwer Academic Publishers, Boston

Färe R, Martins-Filho C, Vardanyan M (2010) On functional form representation of multi-output production technologies. J Prod Anal 33:81-96

Guarda P, Rouabah A, Vardanyan M (2013) Identifying bank outputs and inputs with a directional technology distance function. J Prod Anal 40:185-195

Shephard RW (1953) Cost and production functions. Princeton University Press, Princeton

Shephard RW (1970). Theory of cost and production functions. Princeton University Press, Princeton

Norton, E. and D. Staiger (1994) "How hospital ownership affects access to care for the uninsured" RAND, Journal of Economics 25 (1): 171-185

Dower, C. (2012) Health Affairs

http://healthaffairs.org/healthpolicybriefs/brief_pdfs/healthpolicybrief_73.pdf

Table 1
Descriptive Statistics

	R	X_1	X_2	X_3	Y_1	Y_2	CMI
1994	16	168	186	568	15,299	106,079	1.26
	(72)	(172)	(239)	(708)	(20,149)	(122,757)	(0.22)
1995	17	161	186	556	15,089	113,049	1.25
	(74)	(165)	(235)	(700)	(20,048)	(127,108)	(0.22)
1996	16	158	188	579	15,828	119,468	1.29
	(74)	(162)	(236)	(725)	(21,214)	(135,971)	(0.24)
1997	16	158	191	594	16,087	122,722	1.29
	(70)	(163)	(242)	(751)	(21,891)	(143,930)	(0.24)
1998	17	156	199	603	16,403	130,310	1.27
	(77)	(163)	(258)	(754)	(22,880)	(161,748)	(0.25)
1999	17	157	204	610	16,957	138,895	1.29
	(78)	(164)	(269)	(766)	(23,475)	(164,954)	(0.24)
2000	18	159	210	627	17,383	145,576	1.28
	(80)	(167)	(276)	(792)	(24,209)	(172,514)	(0.25)
2001	18	162	214	652	17,763	153,052	1.26
	(82)	(168)	(283)	(832)	(24,348)	(183,527)	(0.25)
2002	19	170	234	703	19,377	167,674	1.28
	(84)	(170)	(297)	(856)	(25,316)	(190,672)	(0.25)
2003	20	179	254	739	20,703	177,758	1.30
	(87)	(175)	(316)	(885)	(26,157)	(199,368)	(0.26)
2004	23	185	273	770	21,832	187,172	1.30
	(95)	(179)	(338)	(893)	(27,022)	(210,572)	(0.26)
2005	24	188	291	807	22,605	196,586	1.32
	(96)	(181)	(353)	(931)	(27,730)	(216,508)	(0.25)
2006	24	187	299	656	22,449	199,036	1.31
	(98)	(181)	(368)	(783)	(27,847)	(229,369)	(0.26)
2007	27	198	328	861	24,131	209,841	1.35
	(107)	(190)	(401)	(991)	(29,271)	(233,824)	(0.26)
2008	29	208	357	918	25,719	227,813	1.37
	(108)	(194)	(424)	(1,056)	(30,427)	(248,472)	(0.27)
2009	32	220	389	961	27,213	244,350	1.38
	(119)	(201)	(455)	(1,080)	(31,407)	(267,504)	(0.27)
2010	33	223	400	964	27,949	249,900	1.41
	(123)	(203)	(467)	(1,086)	(32,331)	(273,213)	(0.28)

Table 2
Fraction of Statistically Significant Monotonicity Violations by Hospital Type; All Years

	Urban Non-COTH			Rural Non-COTH			Urban COTH		
	# of Hospitals	Monotonicity Violations	Monotonicity Statistically Significant	# of Hospitals	Monotonicity Violations	Monotonicity Statistically Significant	# of Hospitals	Monotonicity Violations	Monotonicity Statistically Significant
Public Hospitals	4443	1.0	97.0	7133	0.0	82.0	930	7.7	84.9
Not-for-Profit Hospitals	21670	0.2	99.3	10033	0.3	79.8	2798	3.1	93.7
For-Profit Hospitals	4978	16.7	78.0	1478	20.4	77.0	94	15.5	68.7

Table 3
Directional Output Distance Function' Monotonicity Evaluated at Mean Values of Regressors; Public Hospitals

Urban Non-COTH Hospitals

	# of Hosp.	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	250	-0.03 *	0.45 *	0.56 *	0.12 *	-0.11 *
1995	244	-0.03 *	0.45 *	0.56 *	0.12 *	-0.10 *
1996	236	0.01	0.46 *	0.55 *	0.11 *	-0.10 *
1997	212	0.00	0.46 *	0.56 *	0.11 *	-0.10 *
1998	205	0.01 *	0.46 *	0.55 *	0.11 *	-0.10 *
1999	208	0.01 *	0.46 *	0.56 *	0.10 *	-0.09 *
2000	187	0.02 *	0.46 *	0.55 *	0.10 *	-0.09 *
2001	200	0.02 *	0.46 *	0.55 *	0.10 *	-0.09 *
2002	196	0.02 *	0.47 *	0.54 *	0.09 *	-0.09 *
2003	178	0.01 *	0.48 *	0.54 *	0.10 *	-0.09 *
2004	369	0.02 *	0.45 *	0.55 *	0.10 *	-0.09 *
2005	353	0.02 *	0.46 *	0.55 *	0.10 *	-0.09 *
2006	355	0.02 *	0.46 *	0.56 *	0.07 *	-0.07 *
2007	348	0.02 *	0.47 *	0.54 *	0.09 *	-0.08 *
2008	330	0.02 *	0.48 *	0.53 *	0.08 *	-0.08 *
2009	291	0.01 *	0.49 *	0.53 *	0.08 *	-0.08 *
2010	281	0.02 *	0.49 *	0.53 *	0.07 *	-0.08 *

Rural Non-COTH Hospitals

	# of Hosp.	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	692	0.04	0.31 *	0.44 *	0.14 *	-0.03
1995	693	0.04	0.31 *	0.44 *	0.13 *	-0.02
1996	688	0.07 *	0.31 *	0.43 *	0.13 *	-0.02
1997	677	0.07 *	0.32 *	0.43 *	0.13 *	-0.02
1998	656	0.08 *	0.32 *	0.43 *	0.12 *	-0.02
1999	648	0.08 *	0.32 *	0.43 *	0.12 *	-0.02
2000	638	0.09 *	0.32 *	0.42 *	0.12 *	-0.02
2001	599	0.08 *	0.32 *	0.42 *	0.12 *	-0.02
2002	491	0.08 *	0.33 *	0.42 *	0.12 *	-0.02
2003	437	0.08 *	0.33 *	0.41 *	0.12 *	-0.02
2004	175	0.09 *	0.31 *	0.42 *	0.12 *	-0.01
2005	171	0.09 *	0.32 *	0.41 *	0.12 *	-0.01
2006	171	0.09 *	0.31 *	0.43 *	0.11 *	-0.01
2007	132	0.08 *	0.33 *	0.41 *	0.11 *	-0.01
2008	106	0.09 *	0.33 *	0.40 *	0.11 *	-0.01
2009	81	0.08 *	0.33 *	0.41 *	0.12 *	-0.01
2010	78	0.08 *	0.33 *	0.41 *	0.11 *	-0.01

Table 3 (continued)

Urban COTH-Member Hospitals

	# of Hosp.	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	54	-0.01 *	0.52 *	0.47 *	0.08 *	-0.22 *
1995	55	0.00	0.36 *	0.43 *	0.23 *	-0.21 *
1996	51	0.01 *	0.64 *	0.34 *	0.12 *	-0.23 *
1997	51	0.01 *	0.53 *	0.53 *	0.06 *	-0.17 *
1998	47	0.00	0.47 *	0.61 *	0.04 *	-0.21 *
1999	53	0.01 *	0.49 *	0.63 *	-0.05 *	-0.14 *
2000	51	0.00	0.45 *	0.56 *	0.07 *	-0.17 *
2001	49	0.00	0.51 *	0.53 *	0.08 *	-0.16 *
2002	47	0.01 *	0.56 *	0.49 *	0.03	-0.10 *
2003	56	0.00	0.48 *	0.56 *	0.05 *	-0.15 *
2004	54	0.00	0.51 *	0.54 *	0.03 *	-0.14 *
2005	54	0.00	0.50 *	0.49 *	0.10 *	-0.17 *
2006	51	0.00	0.50 *	0.57 *	-0.06 *	-0.10 *
2007	64	0.01 *	0.51 *	0.50 *	0.02	-0.17 *
2008	66	0.00	0.52 *	0.53 *	-0.01	-0.15 *
2009	66	0.00	0.52 *	0.56 *	-0.04 *	-0.13 *
2010	61	0.00	0.55 *	0.52 *	-0.02	-0.14 *

* Different from zero at the 5% level of significance in a one-sided test. For the variable measuring the number of residents the test is two-sided.

Table 4
Directional Output Distance Function's Monotonicity Evaluated at Mean Values of Regressors; Not-for-Profit Hospitals

Urban Non-COTH Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	1213	-0.05*	0.38*	0.64*	0.21*	-0.04*
1995	1183	-0.05*	0.38*	0.63*	0.21*	-0.04*
1996	1159	-0.02*	0.40*	0.62*	0.20*	-0.04*
1997	1191	-0.02*	0.40*	0.62*	0.19*	-0.04*
1998	1156	-0.01	0.42*	0.61*	0.19*	-0.04*
1999	1207	-0.01	0.42*	0.61*	0.19*	-0.04*
2000	1194	0.00	0.42*	0.61*	0.19*	-0.04*
2001	1155	0.00	0.42*	0.61*	0.19*	-0.04*
2002	1153	0.00	0.44*	0.60*	0.18*	-0.04*
2003	1151	-0.01	0.44*	0.59*	0.18*	-0.04*
2004	1501	0.00	0.44*	0.59*	0.18*	-0.04*
2005	1483	0.00	0.45*	0.58*	0.18*	-0.04*
2006	1466	-0.00	0.44*	0.58*	0.18*	-0.04*
2007	1424	-0.01	0.47*	0.56*	0.17*	-0.04*
2008	1390	0.00	0.48*	0.56*	0.17*	-0.04*
2009	1334	-0.01*	0.49*	0.55*	0.17*	-0.04*
2010	1310	-0.01	0.50*	0.54*	0.17*	-0.04*

Rural Non-COTH Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	889	0.01	0.27*	0.50*	0.22*	0.00
1995	888	0.02	0.27*	0.50*	0.22*	0.00
1996	871	0.05	0.29*	0.48*	0.21*	0.00
1997	903	0.05	0.30*	0.48*	0.20*	0.01
1998	893	0.06*	0.31*	0.47*	0.20*	0.01
1999	936	0.06*	0.31*	0.47*	0.20*	0.01
2000	931	0.07*	0.31*	0.47*	0.20*	0.01
2001	887	0.06*	0.32*	0.46*	0.20*	0.01
2002	781	0.07*	0.33*	0.45*	0.20*	0.01
2003	738	0.06*	0.34*	0.45*	0.20*	0.01
2004	250	0.07*	0.31*	0.46*	0.19*	0.01
2005	228	0.07*	0.33*	0.45*	0.18*	0.01
2006	238	0.07*	0.31*	0.47*	0.19*	0.00
2007	203	0.06*	0.33*	0.44*	0.18*	0.01
2008	159	0.07*	0.34*	0.45*	0.18*	0.01
2009	119	0.06*	0.34*	0.45*	0.19*	0.01
2010	119	0.06*	0.34*	0.45*	0.18*	0.01

Table 4 (continued)

Urban COTH-Member Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	157	-0.04 *	0.53 *	0.56 *	0.12 *	-0.09 *
1995	154	-0.03 *	0.46 *	0.52 *	0.22 *	-0.08 *
1996	163	-0.01 *	0.65 *	0.46 *	0.14 *	-0.09 *
1997	159	-0.01 *	0.58 *	0.58 *	0.10 *	-0.05 *
1998	161	-0.01 *	0.57 *	0.60 *	0.12 *	-0.09 *
1999	169	-0.01 *	0.57 *	0.62 *	0.07 *	-0.07 *
2000	170	-0.01 *	0.55 *	0.57 *	0.14 *	-0.08 *
2001	165	-0.01 *	0.58 *	0.56 *	0.14 *	-0.07 *
2002	164	-0.00	0.61 *	0.52 *	0.13 *	-0.04 *
2003	174	-0.01 *	0.62 *	0.52 *	0.14 *	-0.06 *
2004	173	-0.01 *	0.63 *	0.52 *	0.14 *	-0.07 *
2005	162	-0.01 *	0.64 *	0.46 *	0.19 *	-0.08 *
2006	163	-0.01 *	0.64 *	0.46 *	0.17 *	-0.07 *
2007	165	-0.01 *	0.68 *	0.43 *	0.13 *	-0.06 *
2008	167	-0.01 *	0.72 *	0.42 *	0.11 *	-0.05 *
2009	166	-0.01 *	0.73 *	0.41 *	0.14 *	-0.06 *
2010	166	-0.01 *	0.76 *	0.39 *	0.14 *	-0.06 *

* Different from zero at the 5% level of significance in a one-sided test. For the variable measuring the number of residents the test is two-sided.

Table 4
Directional Output Distance Function's Monotonicity Evaluated at Mean Values of Regressors; For-Profit Hospitals

Urban Non-COTH Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	234	-0.07 *	0.23 *	0.82 *	0.27 *	0.09 *
1995	254	-0.07 *	0.28 *	0.78 *	0.27 *	0.09 *
1996	273	-0.03	0.30 *	0.77 *	0.25 *	0.09 *
1997	283	-0.03 *	0.29 *	0.78 *	0.25 *	0.09 *
1998	271	-0.03	0.30 *	0.77 *	0.26 *	0.09 *
1999	281	-0.02	0.30 *	0.77 *	0.26 *	0.09 *
2000	288	-0.02	0.30 *	0.77 *	0.27 *	0.09 *
2001	264	-0.02	0.31 *	0.76 *	0.26 *	0.09 *
2002	281	-0.02	0.33 *	0.74 *	0.26 *	0.08 *
2003	298	-0.03 *	0.34 *	0.72 *	0.27 *	0.08 *
2004	357	-0.02	0.35 *	0.71 *	0.27 *	0.08 *
2005	343	-0.02	0.37 *	0.69 *	0.27 *	0.08 *
2006	326	-0.03	0.34 *	0.68 *	0.34 *	0.07 *
2007	339	-0.03	0.38 *	0.67 *	0.28 *	0.08 *
2008	306	-0.03	0.40 *	0.66 *	0.28 *	0.08 *
2009	294	-0.04 *	0.42 *	0.64 *	0.28 *	0.08 *
2010	286	-0.03 *	0.42 *	0.63 *	0.29 *	0.08 *

Rural Non-COTH Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	108	-0.01	0.12 *	0.66 *	0.33 *	0.10 *
1995	116	-0.01	0.15 *	0.64 *	0.33 *	0.10 *
1996	109	0.03	0.17 *	0.62 *	0.31 *	0.10 *
1997	123	0.02	0.17 *	0.62 *	0.31 *	0.10 *
1998	123	0.03	0.17 *	0.62 *	0.32 *	0.10 *
1999	125	0.03	0.17 *	0.62 *	0.32 *	0.10 *
2000	129	0.04	0.18 *	0.61 *	0.32 *	0.09 *
2001	125	0.04	0.18 *	0.62 *	0.32 *	0.09 *
2002	124	0.04	0.18 *	0.61 *	0.32 *	0.09 *
2003	139	0.03	0.19 *	0.60 *	0.32 *	0.09 *
2004	38	0.04	0.19 *	0.59 *	0.31 *	0.09 *
2005	37	0.04	0.20 *	0.58 *	0.31 *	0.09 *
2006	37	0.04	0.20 *	0.57 *	0.33 *	0.08 *
2007	37	0.03	0.24 *	0.55 *	0.29 *	0.09 *
2008	35	0.04	0.25 *	0.54 *	0.29 *	0.09 *
2009	34	0.03	0.22 *	0.57 *	0.30 *	0.09 *
2010	39	0.03	0.22 *	0.56 *	0.30 *	0.09 *

Table 5 (continued)

Urban COTH-Member Hospitals

	#	Residents	Beds	Registered Nurses	LPN&Other Personnel	Outpatient Activity
1994	1	0.01	0.09	1.52 *	-0.26 *	0.10 *
1995	2	0.03	0.47 *	0.89 *	0.02	0.06
1996	1	-0.02	0.58 *	0.80 *	0.08 *	0.08 *
1997	2	-0.03	0.58 *	0.87 *	0.07 *	0.04 *
1998	6	0.00	0.60 *	0.68 *	0.32 *	-0.03
1999	7	-0.01	0.73 *	0.63 *	0.24 *	-0.02
2000	10	0.01	0.59 *	0.84 *	0.05	0.05
2001	8	0.01	0.92 *	0.60 *	-0.09	0.10 *
2002	7	-0.01	0.80 *	0.62 *	0.11 *	0.05 *
2003	7	-0.02	0.77 *	0.65 *	0.06 *	0.08 *
2004	4	-0.03 *	0.77 *	0.54 *	0.21 *	0.07 *
2005	8	-0.06 *	1.13 *	0.27 *	0.17 *	0.05 *
2006	7	-0.04 *	0.92 *	0.34 *	0.29 *	0.06 *
2007	6	-0.05 *	0.93 *	0.36 *	0.25 *	0.06 *
2008	7	-0.03	0.97 *	0.37 *	0.17 *	0.08 *
2009	6	-0.05 *	1.01 *	0.32 *	0.21 *	0.07 *
2010	5	-0.05 *	1.01 *	0.29 *	0.24 *	0.07 *

* Different from zero at the 5% level of significance in a one-sided test. For the variable measuring the number of residents the test is two-sided.

Table 6
Ex Post Status of Residents – Fraction of Observations per Group of Hospital

	Urban Non-COTH				Rural Non-COTH				Urban COTH			
	#	Input	Output	Ave. CMI	#	Input	Output	Ave. CMI	#	Input	Output	Ave. CMI
Public Hospitals	4443	78 (66)	22 (17)	1.26	7133	100 (79)	0 (0)	1.07	930	59 (42)	41 (24)	1.68
Not-for-Profit Hospitals	21670	37 (6)	63 (35)	1.38	10033	99 (55)	1 (0)	1.15	2798	23 (10)	77 (56)	1.71
For-Profit Hospitals	4978	4 (1)	96 (25)	1.38	1478	87 (1)	13 (0)	1.16	94	27 (4)	73 (25)	1.69

Note: The fraction of statistically significant cases is given in parentheses

Table 7
Status of Residents at Urban Area Not-for-Profit Non-COTH Hospitals

	# of Hosp.	Ave. # of beds	Input	Output	Ave. CMI
Small	2014	35	82 (41)	18 (8)	1.13
Medium-Sized	12237	142	50 (5)	50 (20)	1.32
Large	7419	367	2 (0)	98 (67)	1.54